The Application of Blockchain in Intelligent Power Data Exchange

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ABSTRACT

The State Grid ETL(SG-ETL) tool, based on Extract,Transform and Load(ETL) technology, has important application value in intelligent power data exchange. As an important part of the transmission component in the power grid system, it realizes the data exchange between power systems, but in the process of data exchange, problems are gradually exposed such as unguaranteed data quality and uncontrolled business process. In this respect, this thesis studies the blockchain technology and analyzes its feasibility in the application of intelligent power data exchange, optimizes the power transaction order management business process from the blockchain perspective as example, proposes the Decentralized Transaction credit model based on Blockchain P2P(DTBP) according to the process, and describes its evaluation algorithm, introduces the idea of "chain on the chain" to plan the scheme of data to chain in the data exchange process, designs the smart contract life cycle,formulates contract rules and interface function conventions, uses the JSPIN tool to design the third convention's Promela mode, verifies the data and analyse the result to solve the data exchange problems finally.

CCS CONCEPTS

•General and reference•Information systems~Information systems applications~Enterprise information systems~Enterprise applications•Information systems~Information systems applications~Enterprise information systems

KEYWORDS

Blockchain, Power transaction, Data exchange, DTBP trust model, Smart contract

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1 Introduction

With the continuous increasing number of power users around the world, power grid companies are beginning to expand production scale, improve business models, and promote the construction of energy internet. In this process of construction and reform, the massive data in the power grid information system presents inadequacies such as complex structure, low credibility etc. It is urgent to introduce new technologies to support the development of information systems to meet the diverse business needs of the new era.

The continuous emergence of new computer technologies provide more solutions for power grid information systems, blockchain technology can be applied to the exchange of power data to enhance the security and sharing ability [1]. The payment of power transaction bills using a network based on blockchain technology to solve the problem about transaction trust without any centralized agency coordination and review, so that all nodes can exchange and share data in a trustless environment.

This thesis first studies the short comings of using ETL tools, then introduces blockchain technology, uses blockchain to take power transaction order management as an example to redesign business processes, describes a transaction trust model and evaluates algorithm, then introduces the "chain-on-chain" idea to plan the data-chaining scheme, designs the life cycle and rules for the smart contract, takes the treaty three as an example for experimental verification, finally, through analysis the business process control issues that encountered during the data exchange to improve the smart power data quality.

2 IPDX Overview

2.1 IPDX Based on ETL Tool

Intelligent Power Data Exchange (IPDX) is a kind of data exchange in the power energy trading community [2], which can realize the business data for various departments in the power system from the headquarters to the network province, the network province to the network province.

Data extraction, conversion and loading [3], is a method of extracting the source database data into the temporary database, then cleaning, converting and integrating the data, and finally loading it into the target database. IPDX uses ETL tools for data exchange, and its architecture is shown in the Figure 1 bellow.

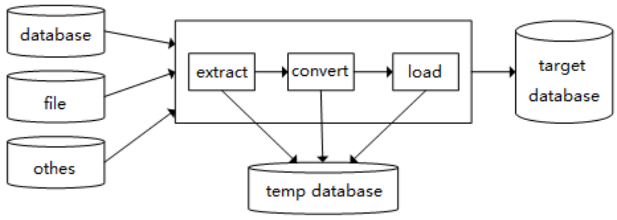

Figure 1: ETL architecture

2.2 Problems with IPDX

Due to the characteristics of uneven distribution and large number of companies and business systems in the power system, the management of data exchange within the system has become complicated. At present, the IPDX system has exposed the following two deficiencies during its operation:

1. After the company develops new business and new partners, it is difficult for the system to perform a credit analysis on the newly joined members, so that the new members may make false data during data exchange, which affects the data quality.
2. In the process of data exchange management of power transaction orders, the system lacks perfect management over the order payment process, so that the payer arrears money in the performance of the contract, causing the system to fail to exchange data normally.

3 Blockchain Technology

3.1 Blockchain Overview

The blockchain is a data structure composed of multiple small data blocks with various information recorded through the chain [4]. As shown in Figure 2, each block is the basic unit of the blockchain, the block header is connected to the next block header. In 2015, the blockchain was divided into 1.0, 2.0 and 3.0 three levels by Swan [5]. The database in blockchain 1.0 does not have a central node and is not stored independently on a computer, but is distributed and publicly stored and shared in a huge network composed of many nodes. All nodes participate in maintaining the account update, each node have equal rights to check the database records generated in order of time. The emergence of smart contracts enables blockchain 2.0 to automatically execute preset program codes on the basis of signed contracts in a programmatic manner, thereby fulfilling the terms and avoiding disputes over traditional electronic contracts. Blockchain 3.0 revolutionized the programmable society, which is to further expand programming technology into many fields of society, such as finance, insurance, logistics, energy, etc., improves social services, subverts traditional business models, and constructs a global internet of things for accounting system.

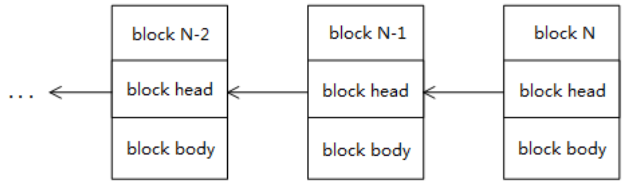

Figure 2: Blockchain composition structure

3.2 Feasibility Analysis of the Application of Blockchain in IPDX

In view of the shortcomings exposed by the current IPDX system during its operation, combined with the relevant technical characteristics of the blockchain, the blockchain is applied to IPDX due to the following two points:

1. Due to the decentralization and sharing of the blockchain, you can analyze the credit of new members by introducing a transaction trust model and evaluation algorithm in an environment of mutual distrust, and then share the analysis results in the blockchain ledger, the other members of the network will make the next decision for the new member based on the synchronization result.
2. Since the smart contract technology in the blockchain has the ability to automatically execute the clause code in the signed contract when certain conditions are met, the order payment function in the automated power transaction contract can be realized in time, and the payment is no longer in arrears. So that the IPDX system can exchange data normally.

4 Design of IPDX Scheme based on Blockchain

4.1 Business Process Design

The power transaction order management process in the intelligent power data exchange system is shown in Figure 3. Among them, party A is a power user, and party B is a power sales unit. The following will design the credit evaluation, data upload, and smart contract according to this business process.

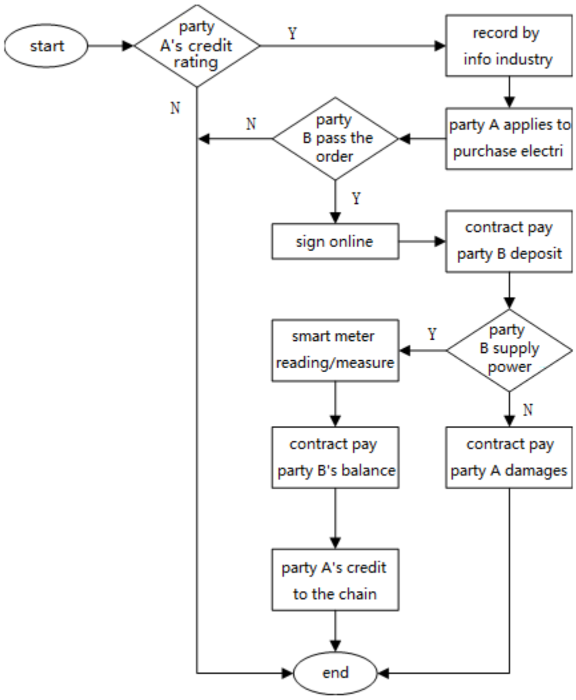

Figure 3: Power transaction order management process

4.2 Transaction Trust Model and Evaluation

Algorithm Description

4.2.1 Definition of DTBP Model

DTBP (Decentralized Transaction credit model based on Blockchain P2P), that is, a decentralized transaction trust model based on the blockchain P2P network. The model is designed using some classic node trust model indicators based on the combination of transaction history and recommendation degree. Carry out the following formal definition :

Definition 1: According to the node i and j transaction success and failure times S_{ij} and F_{ij}, define the untrustworthy factor ε :

$$\varepsilon=\varepsilon+F_{ij}/\left(S_{ij}+F_{ij}\right) \quad (1)$$

Definition 2: Define the partial trust degree $P(i)$ of the node i to the node j according to the untrustworthy factor:

$$P(i)=S_{ij}\bullet(1-\mu)^{1/(S_{ij}+\varepsilon F_{ij})}/(S_{ij}+\varepsilon F_{ij}) \quad (2)$$

Among them, μ is the partial trust control factor, and $0<\mu<1$;

Definition 3: When the transaction of node i and j are completed, define the satisfaction A_{ij} of the node i to the node j :

$$A_{ij}=\mathrm{Vaild}_j/(\mathrm{Vaild}_j+\mathrm{All}_j) \quad (3)$$

Among them, Vaild_j and All_j are the effective overall information size that obtained by the node i from the node j, and $0\le A_{ij}<1$;

Definition 4: According to the success times D_{sj} and failure times D_{fj} of downloading resources from the node i to the node j, define the recommendation factor λ_{ij}:

$$\lambda_{ij}=D_{si}\varphi(D_{si},D_{fi})/(D_{si},D_{fi}) \quad (4)$$

Among them, if $D_{si}>0$,then $\varphi(D_{si},D_{fi})=(D_{si},D_{fi})^{-1/D_{si}}$;

Definition 5: Define the performance value $\phi(i)$ according to the amount M_i of information contributed by the node i to the system:

$$\phi(i)=(M_i e)^{-1/M_i},M_i>0 \quad (5)$$

Among them, e is a constant in mathematics;

Definition 6: After the transaction, the participating nodes that define the transaction get the evaluation trust factor α_{ij} from the initiating node:

$$\alpha_{ij}=(1-\mathrm{Trust}(j))P(i)+\mathrm{Trust}(j)\bullet((1+\lambda_{ij})/e) \quad (6)$$

Among them, $\mathrm{Trust}(j)$ is the trust degree of the node j;

Definition 7: In a P2P distributed network, the contribution $C(i)$ that nodes i to the system is defined according to the number n of transactions between nodes j and nodes i :

$$C(i)=\sum_{i=1}^{n}A_{ij}\phi(i) \quad (7)$$

Definition 8: According to all the above indicators, finally define the trust degree $\mathrm{Trust}(i)$ of the node:

$$\mathrm{Trust}(i)=\begin{cases}\beta C(i)+\dfrac{1-\beta}{m}(\sum_{k=1}^{m}\alpha_{ki})e^{-1/\sqrt{m}}\\ \beta=\phi(i)/\sum_{i=1}^{n}\phi(i)\end{cases} \quad (8)$$

Among them, m is the total number of nodes participating in the evaluation, β is the control factor of the contribution degree, and $0<\beta<1$, $\beta C(i)$ is the self-trust degree of the node i, $\frac{1-\beta}{m}(\sum_{k=1}^{m}\alpha_{ki})e^{-1/\sqrt{m}}$ is the average value of the trust evaluation of other nodes in the system after its transaction.

4.2.2 Evaluation Algorithm Description

The description of the evaluation algorithm steps is shown in the Table 1 bellow.

Table 1 Description of evaluation algorithm steps

Algorithm 1: DTBP evaluation algorithm
1. Initialize S_{ij}, F_{ij}, ε, μ, n, m;
2. Calculate ε and $P(i)$, if $S_{ij}+\varepsilon F_{ij}=0$, then $P(i)=0$;
3. Calculate A_{ij} and $\phi(i)$;
4. Calculate $C(i)$, λ_{ij} and α_{ij};
5. Calculate $\mathrm{Trust}(i)$;

4.3 Data on-chain Design

Data on-chain refers to the process of uploading and saving the data in the database to the blockchain safely and quickly to form an index. The power transaction order data will be divided into the following two steps for data on-chain design:

Step 1: For real-time order data, use the SG-ETL tool to extract and clean the quasi-real-time data in the production library; For historical order data, during business idle periods, by setting a scheduled task to the library through the SG-ETL scheduling monitoring system to extract and clean data.

Step 2: Assemble the data collected by the SG-ETL tool into a blockchain transaction order and submit it to the on-chain chain system through the RPC interface. The main chain in the on-chain chain is responsible for transaction-related operations. The side chain one is responsible for data storage, and the second is responsible for data analysis and calculation. As shown in the Figure 4 bellow.

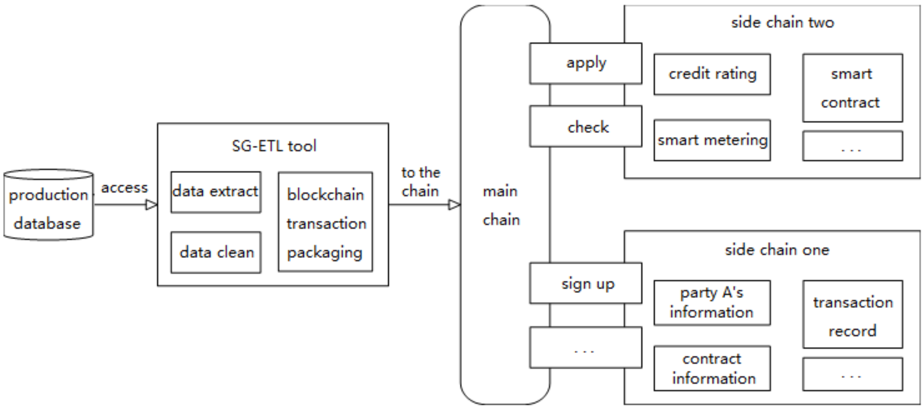

Figure 4 Power transaction order data on the chain

4.4 Smart Contract Design

In 1994, Szabo[6] innovatively proposed smart contracts, which aimed to use digital technology to solve the problem of property conflicts in traditional electronic transactions, but they were not applied at that time. Until 2013, smart contracts started to operate efficiently by the chain 2.0 technology , mainly by automatically executing the pre-written program code on the chain to fulfill the terms of the transaction contract, thereby avoiding the intervention of third-party intermediaries and realizing the intelligent transaction of the contract.

In the power transaction order blockchain, the life cycle of the smart contract includes: order generation, online signing and contract fulfillment, as shown in the Figure 5 bellow.

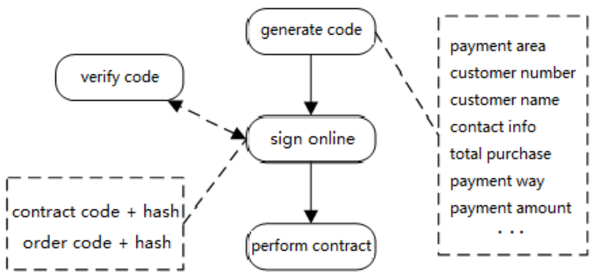

Figure 5 Smart contract life cycle

1. Order generation: Party A fills in the information required for the power purchase order, such as payment area, customer number, customer name, contact information, total power purchase amount, usage period, payment method, payment amount, etc.

2. Online signing: After party A submits the order, party B starts to review the details of the order, the execution code of the smart contract and its hash, etc. In order to check whether the contract code meets the specification requirements, the code needs to be formally verified [7]. Formal verification methods such as automated model detection method and theorem proving method are commonly used, and detection tools such as JSPIN, UPPAAL, NuSMV, etc. are commonly used[8]. After confirming that the code is correct, party B needs to sign the contract and upload it to the blockchain to save it, so as to complete the entire process of online signing.
3. Contract performance: After the two parties sign the contract online, the execution of the contract is carried out by the program code under certain conditions to execute the terms of the contract to complete the prepayment, deduction and settlement of the order funds. The specific terms and rules are as follows:

Rule 1: After signing the contract, party A pays 30% of the total contract price as deposit to party B .

Rule 2: During the contract period, if the total amount of electricity consumed by party A is less than 10% of the total amount of electricity purchased by the contract, the actual total amount will be calculated according to the total amount of electricity used multiply unit price, and the total amount returned to party A will be deposit actual total amount; If party A's actual electricity consumption is higher than 10% but less than 60% of the contract total electricity purchase, the actual total amount will be calculated according to the actual electricity consumption multiply unit price, and no longer refund of the deposit; If the actual total electricity consumption of party A is higher than 60% but less than 90% of the total contract electricity purchase, the actual electricity consumption multiply unit price and reduce deposit and plus total electricity purchase price and multiply 10% to calculate the actual total amount; If party A's actual electricity consumption is higher than 90% but less than 110% of the contracted electricity purchase, the actual total electricity consumption will be calculated based on the actual electricity consumption multiply unit price and reduce deposit; When the total amount of electricity consumed by party A is higher than the total contracted electricity purchase by 110%, an additional 5% of the total purchase price will be charged as a penalty.

Rule 3: During the contract period, if the total power supply of party B is less than 30% of the total power purchase of party A, the full deposit will be refunded to party A; If the total power supply of party B is higher than 30% but less than 90% of the total power purchase of contract A , the total amount of party A will be charged: actual power supply amount multiply unit price and reduce deposit and reduce total power purchase price and multiply 10%; If the total power supply of party B is higher than 90% but less than 100% of the total amount of the contract party A purchase, the total amount of party A will be charged: actual power supply amount multiply unit price and reduce deposit and reduce total power purchase price and multiply 5%; If the total amount of power supply of party B is greater than or equal to the contract that party A purchases, the total amount of party A will be charged: total amount of electricity purchase multiply unit price and reduce deposit.

5 Experiment and Conclusion

Smart contracts are the core part of the IPDX transaction order management process. Writing standardized program codes and conducting formal verification will facilitate the correct and efficient performance of the contract. This smart contract is developed in Solidity language, and the abstract contract interface function conventions are written according to the three rules in the contract, as shown in the Figure 6 bellow.

```
pragma solidity ^0.4.0;
contract TradeOrder {
//Agreement 1: Party A pays the deposit contract function
function convention_1( address purchase, unit prepayment )
            public returns( address,string );
//Agreement 2: Party A's actual electricity use contract function
function convention_2( address purchase, unit real_use )
            public returns( address,string );
//Agreement 3: Party B's actual power supply contract function
function convention_3( address sale, unit real_supply )
            public returns( address,string );
}
```

Figure 6 Abstract contract interface function convention

The model design and detection tool of this smart contract is JSPIN, which uses Promela modeling language to describe the specifications of the system model.

Using Promela language specification and taking convention three as an example to do some follow describes:

```
active proctype convention_3(int buyer_acount,int real_suply,int
contract_amount,int unit_price,int advance_payment) {
   // The process of agreement 3
   bool supply=false // Power supply sign
   do
    ::(supply==false)->atomic
          {supply=true;}// Party B starts to supply electricity
      if
      ::(0<=real_suply<contract_amount*0.3)->atomic
      { buyer_acount+=advance_payment;break; }
      ::(contract_amount*0.3<=real_suply<contract_amount*0.
9)
      { buyer_acount=real_suply*unit_price-advance_p
```

```
ayment-contract_amount*unit_price*0.1;break; }
        ::(contract_amount*0.9<=real_suply<contract_amount)
        { buyer_acount=real_suply*unit_price-advance_payment-
contract_amount*unit_price*0.05;break; }
        ::(contract_amount<=real_suply)
        { buyer_acount=contract_amount*unit_price-advance_pay
ment;break; }
        ::else
        fi
    od
}
```

The verification results of convention 3 are shown in Tables 2 and 3, which are 10 pieces of sample data randomly selected from 1000 pieces of simulated data that passed verification and failed verification.

Table 2 Random data verified in the third agreement

no.	purchase	supply	proportion	unitprice	deposit	payable
1	300	300	100	1.2	108	
252						
2	900	207	23	1.2	0	0
3	600	492	82	1.2	216	302
4	5000	4750	95	0.5	750	1500
5	2000	240	12	0.5	0	0
6	8000	8160	102	0.5	1200	2800
7	42000	36120	86	0.3	3780	4410
8	27800	27244	98	0.3	2502	5254
9	64500	14190	22	0.3	0	0
10	10300	10712	104	0.3	927	2163

Table 3 Random data that failed verify in the third agreement

no.	purchase	supply	proportion	unitprice	deposit	payable
1	400	380	65	1.2	100	313
2	800	830	103	1.2	20	540
3	500	500	100	1.2	150	325
4	7200	7100	99	0.5	340	3500
5	3000	100	5	0.5	0	300
6	6600	7400	122	0.5	1400	310
7	36500	36500	100	0.3	3380	3570
8	58200	27244	52	0.3	1513	215
9	13900	14210	107	0.3	756	0
10	42200	41712	95	0.3	458	963

It can be seen from Table 2 that the deposit of each contract and the data of party A's payable data are calculated strictly according to the terms of the third agreement, but the data in Table 3 is not calculated by the third agreement, so it will not be passed from model verification.

6 Conclusion

This thesis uses blockchain technology to solve the data quality and business process problems encountered in the application of SG-ETL tools in intelligent power data exchange, redesigns the business process of power transaction order management, and integrates the blockchain trust model, data on-chain and smart contract. In the distrust model part, this thesis proposes a node trust model DTBP model based on the combined calculation of the transaction history and recommendation degree of the blockchain P2P network, and describes the algorithm of the model. In the data on-chain part, this thesis cites the idea of "chain on chain" to design the data uploading scheme in two steps, make the main chain and the two side chains responsible for different tasks. In the smart contract part, this thesis designs its life cycle into three stages. Finally, this thesis writes abstract contract interface function convention, and uses the JSPIN tool to write the Promela modeling code of convention three, and verifies the correctness of the contract through two sets of randomly drawn sample data.

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